ARMY RESEARCH LABORATORY

Converting Between PLY and Ballistic Research Laboratory–Computer-Aided Design (BRL-CAD) File Formats

by Rishub Jain

ARL-CR-0760 **February 2015**

Prepared by
American Society for Engineering Education (ASEE)
1818 N Street, NW
Washington, DC 20036

Under contract

W911NF-10-2-0076

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Army Research Laboratory
Aberdeen Proving Ground, MD 21005

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14. ABSTRACT

The basis of this project was to complete the 2-way conversion between Stanford PLY and Ballistic Research Laboratory–Computer-Aided Design **(**BRL-CAD) file formats by utilizing the open source C RPly library. The existing converter that converts Stanford PLY files to BRL-CAD's file format was improved by implementing binary PLY file support and increasing overall speed. Binary PLY files are much smaller and quicker to process, and are necessary for large data. Then, a converter was developed that changed BRL-CAD files to PLY files. These converters will allow many more researchers to use BRL-CAD's resources, and expand BRL-CAD's applications and usability.

15. SUBJECT TERMS

Ballistic Research Laboratory–Computer-Aided Design, BRL-CAD, PLY, conversion

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Student Bio

Rishub Jain is currently a rising senior at Thomas Jefferson High School for Science and Technology. Last summer, he was an intern at National Aeronautics and Space Administration (NASA) Goddard Space Flight Center, working on processing satellite images for the IMAGEs for Science, Education, Experimentation and Research (IMAGESEER) web site. He plans to major in Computer Science.

1. Introduction and Background

Ballistic Research Laboratory–Computer-Aided Design (BRL-CAD) is an open source solid geometry modeling system used by researchers around the globe. It has a multitude of different services, including the capability to convert between several different geometric information file formats, such as PLY, and its own BRL-CAD file format. The Stanford PLY file format is a simple object description made to be convenient for researchers to model a collection of polygons. These files store data in either text or binary modes. BRL-CAD's G (also known as ".g") file format is a geometry database file used by BRL-CAD for modeling objects. A converter that changes PLY file types to the G format already exists but only works for PLY files in the American Standard Code for Information Interchange (ASCII) format.

The goal of this project is to work on this converter so that it supports binary PLY files by utilizing the open source C RPly library to parse PLY files. Binary PLY files are much smaller and quicker to process, and are therefore highly desirable for large data sets. This project also involves creating a converter that changes PLY files to the G format. The results of this project will allow researchers who use the binary PLY file format to efficiently use all of BRL-CAD's features and tools, and expand BRL-CAD's applications and usability. Also, this project supports Joint Aircraft Survivability Program (JASP) Target Geometry Conversion objectives by contributing to a unified conversion library between different geometry file formats.

2. Experiment and Calculations

2.1 Preliminary Work

Before I received my networked computer account, I worked on a stand-alone computer digitizing videocassettes using the Final Cut Express software package. These videos covered BRL-CAD's history dating back as far as 3 decades ago using various videocassette recorder (VCR) formats. This project showed me how rich BRL-CAD's history is and gave me an introduction to video production.

Once I received my account, I initially worked on fixing bugs in the BRL-CAD's source code. I added BRL-CAD's retracing hypersampling feature to the functions rtweight and rtarea, so multiple data points could be taken for each pixel to increase accuracy. I then updated the documentation to include this. I also fixed a bug where the function rtweight was stuck in an infinite loop when it was given corrupt data. This helped me get accustomed to the large code base and become familiar with the process of updating the source code.

2.2 ply-g Converter

Part of the final project was to improve the existing PLY to BRL-CAD converter by supporting binary PLY conversion since the existing converter only supported ASCII PLY files. Binary PLY files are the only practical way to store large data because they are much quicker to process and are much smaller (as shown in Figs. 1 and 2). Also, the conversion process did not retain any other information, such as color, besides the vertices and faces of the polygons. The new converter uses RPly, an open source C library available under the Massachusetts Institute of Technology (MIT) License, to efficiently collect data from PLY files, and is even slightly faster than the method the existing converter uses. This library uses callbacks to perform a different function for each type of data, such as vertex or face, while parsing the file. After obtaining the data, the new converter creates a "Bag o' Triangles" object, a 3-dimensional (3-D) shape bounded by a mesh of small triangles, using BRL-CAD's function mk_bot. Then, if the object has 1 solid color, it is put into a region in which the color can be specified. This is all outputted into a single .g file, which can be used by BRL-CAD's vast collection of tools, such as a geometry editor like the Multi-Device Geometry Editor (MGED) or Archer.

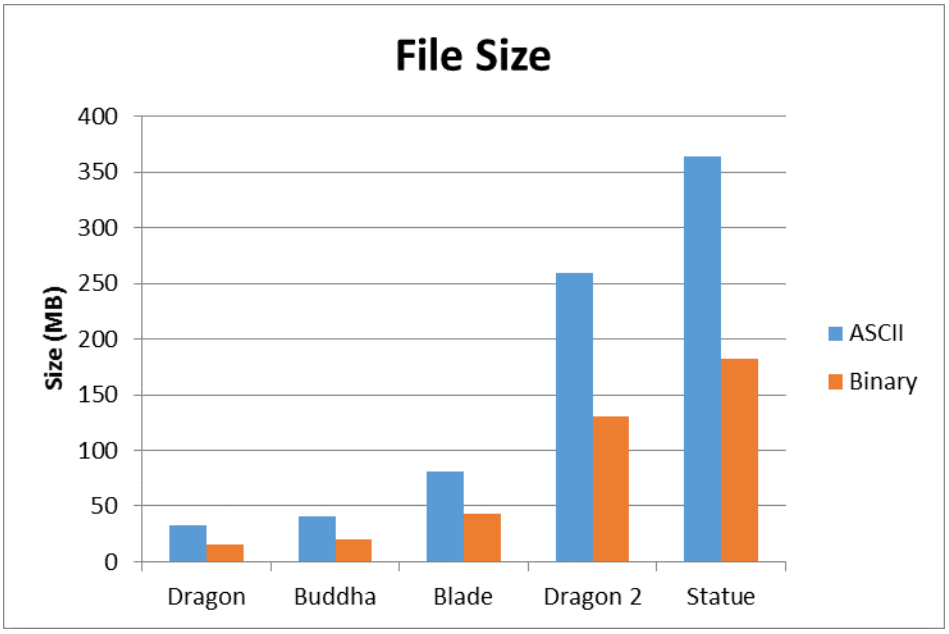

Fig. 1 Binary file size comparisons

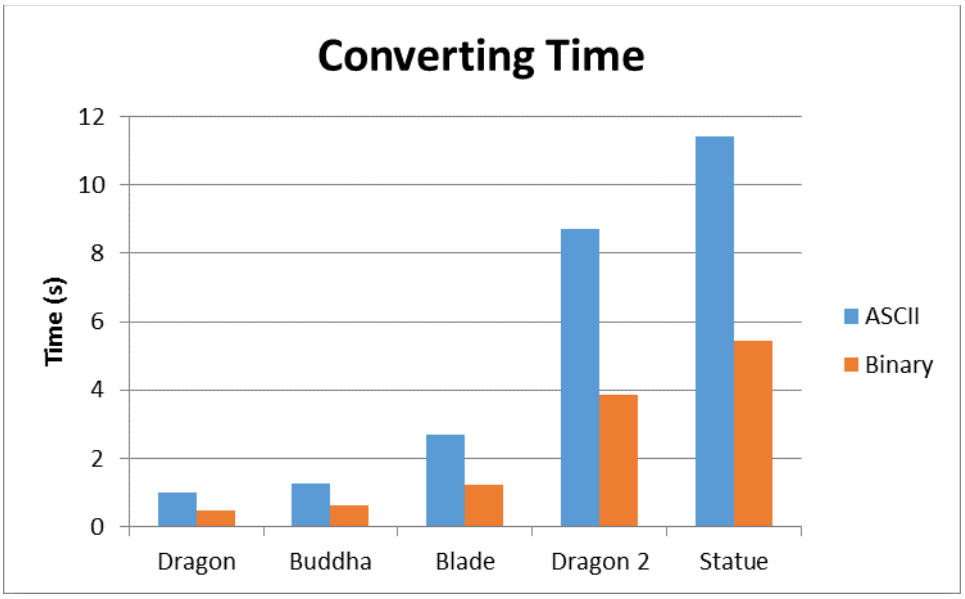

Fig. 2 Binary converting time comparisons

2.3 g-ply Converter

The second part of my project was to develop a program that converted BRL-CAD files to the PLY format. This conversion first utilizes the g-nmg tool, which converts the BRL-CAD's primitives to N-Manifold Geometries (NMG), which are shapes that are bounded by a mesh of polygons. Then these polygons are triangulated since the PLY format is usually only composed of the faces and vertices of triangles. The faces and vertices of each specified region of the file are then stored and written to the PLY file or files using the RPly library. A command line option can specify the data storage type, as PLY files can be written in binary or ASCII. A major problem that I encountered was that each PLY file can only hold 1 object, so multiobject BRL-CAD files had to be either combined into 1 file or separated into several files. Giving this choice to the user, I made the default option to combine the objects and added an option to create a separate file for each nonempty object, named by its hierarchy and name.

2.4 Data Collection for step-g Converter

Near the end of my internship I also went on a weeklong offsite activity where the focus was to robustly import solid geometry from ISO Standard for the Exchange of Product (STEP) AP203 format. I had worked with Matthew Bays, a college intern, to collect data from the existing step-g program by converting hundreds of STEP files to the BRL-CAD format, and reporting any errors or incorrect output geometry. We used STEP files from the Internet and from my student-mentor's, (Mr Morrison's) own resources, and created a spreadsheet with all our information. Also, we had compared the performance of converting triangle meshes in the Standard Tessellation Language (STL) file format to BRL-CAD and converting STEP files that use the Nonuniform rational B-spline (NURBS) model to BRL-CAD. These tests will be used as a

baseline to show any improvement in the speed of the step-g converter when it later becomes more efficient.

3. Results and Discussion

Both converters are fully functional, and I have reached my goals for this summer. Through extensive testing, I have found and fixed several bugs with the new ply-g converter, such as a file naming problem when converting files in other directories. The ply-g program correctly converts all vertex, face, and color information for all triangular meshes, and just ignores any additional attributes. Also, support for converting extra properties from the PLY file can be easily implemented in the future if it is also supported in BRL-CAD. The g-ply converter has also been greatly tested and worked flawlessly for many BRL-CAD files. However, for a few files, the NMG tool is unable to convert the primitive to an NMG model. Also, the conversion is not entirely lossless since there are a few attributes in BRL-CAD files that PLY files do not conventionally have. Although, most researchers who use PLY files only use the face and vertex information; the code is designed so this can be easily included in the future.

4. Summary and Conclusions

During my summer working on the BRL-CAD project, I have learned more than I ever expected to while also being able to improve BRL-CAD. I had never worked on an open source project before, and starting off with such a large codebase was very challenging and a great learning experience. By constantly working in a Linux environment, I learned how to efficiently use the Linux commands and tools. Also, I realized how much there was to learn about the C language, and was able to learn so much even though I thought I already knew all the basics. My ply-g and g-ply converters will increase BRL-CAD's functionality and usability, leading to more researchers benefiting from it. Also, the converters will help achieve one of BRL-CAD's goals to create a unified conversion library. I loved figuring out things on my own and also collaborating with other US Army Science and Engineering Apprenticeship Program (SEAP) students, and I am excited to continue working on this project in my free time.

List of Abbreviations, Acronyms, and Symbols

3-D	3-dimensional
ASCII	American Standard Code for Information Interchange
ASEE	American Society for Engineering Education
BRL-CAD	Ballistic Research Laboratory Computer-aided Design
IMAGESEER	IMAGEs for Science, Education, Experimentation and Research
JASP	Joint Aircraft Survivability Program
MGED	Multi-Device Geometry Editor
MIT	Massachusetts Institute of Technology
NASA	National Aeronautics and Space Administration
NMG	N-Manifold Geometries
NURBS	Nonuniform rational B-spline
SEAP	Science and Engineering Apprenticeship Program
STEP	Standard for the Exchange of Product
STL	Standard Tessellation Language
VCR	videocassette recorder

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